NASA SBIR/STTR Technologies

H7.02-9691 - Short Pulsed Laser Methods for Velocimetry and Thermometry in High Enthalpy Facilities

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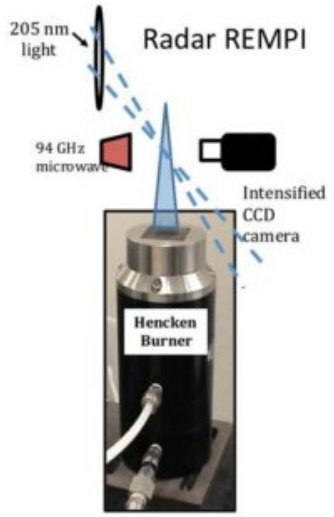
Identification and Significance of Innovation

A suite of pulsed laser diagnostics is proposed for studying aspects of planetary entry and Earth atmospheric reentry in arc jets. For example, dissociation of molecules impacts the flow-field physics, including surface heat flux and catalytic surface reactions. Results obtained during the Phase I effort point to three promising diagnostic techniques: Rayleigh Scattering Polarimetry (RSP) for dissociation fraction, Thermal Acoustic Wave (TAW) thermometry for gas temperature, and Radar Resonance Enhanced Multi-photon Ionization (Radar REMPI) for gas temperature and velocity. The RSP technique is based on the differences in the polarization of Rayleigh-scattered light between atoms and molecules. The TAW technique is based on the determination of wave speed from the propagation of an acoustic wave generated by a laser spark from the focused beam of a pulsed laser. In the case of Radar REMPI, temperature and velocity are obtained through the spectral broadening and frequency shift associated with two-photon resonance interactions in atomic oxygen and nitrogen.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 6)

Technical Objectives and Work Plan

A detailed work plan has been developed to meet the following technical objectives. 1. Develop facility to produce conditions of arc jet flows. 2. Develop model for the temperature variation of Rayleigh cross-section and depolarization ratio. 3. Demonstrate measurements of dissociation fraction using RSP at high temperatures and low densities. 4. Recommend RSP system configuration compatible with NASA arc jet facilities. 5. Determine the optimum laser strategy for generating consistent acoustic waves in low density gases. 6. Develop a model to predict acoustic wave strength at arc jet facility conditions, and validate experimentally. 7. Develop a methodology to obtain temperature from wave speed, and demonstrate in relevant mixtures. 8. Recommend a TAW system configuration for the NASA arc jet facilities. 9. Establish the temperature and velocity sensitivity of Radar REMPI measurements compared to TALIF. 10. Calibrate the Radar REMPI technique using CARS for the vibration states of nitrogen and oxygen. 11. Examine the effect of increased power pulsed microwaves to improve the signal sensitivity of Radar REMPI. 12. Develop a narrow linewidth laser to conduct Radar REMPI experiment in atomic oxygen and argon. 13. Recommend a Radar REMPI system for the NASA arc jet facilities.

NASA Applications

The proposed diagnostics are needed in test programs for atmospheric reentry and planetary entry at NASA's arc jet facilities, hypersonic wind tunnels, and shock tunnels. Non-intrusive unseeded measurements of temperature, velocity, and dissociation are required for validating fluid/chemistry models that incorporate real-gas kinetics, including those used to predict planetary entry aerothermodynamics. The diagnostics can serve as tools in very high enthalpy flow experiments that focus on testing the integrity of thermal protection systems.

Non-NASA Applications

The unique capability to measure temperature, velocity, and dissociation fraction in high enthalpy flows will be attractive to the private space industry, including low Earth orbit and planetary exploration. Programs include delivery of cargo and astronauts to the ISS, and deep space exploration, i.e. involving Mars. Other applications are combustion diagnostics in premixed and diffusion flames.

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